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Scientific Journal of Mehmet Akif Ersoy University, 2024, 7(2), Page:91-98

Research Article

Wideband Microstrip Patch Antenna Design At 2.4 Ghz Frequency for Wireless Communication

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ABSTRACT

The ever-increasing development of wireless and mobile communications, along with the rising volume of data and data traffic in wireless networks, requires these communications to be fast and uninterrupted. This can be achieved through the development of antennas with low return loss, high bandwidth, and compact size. In this study, an antenna design operating at a 2.4 GHz frequency was created using the CST Microwave Studio program to meet the need for broadband microstrip patch antenna designs. FR-4 material, which is 1.6 mm high, has a dielectric constant of 4.3 and a rectangular geometry with a loss tangent of 0.019, was used as the substrate material. At a resonance frequency of 2.4 GHz, the antenna was found to have a maximum gain of 2.27 dB and a maximum directivity of 7.28 dB in the same direction. Selection of new microstrip patch antenna configurations and development of accurate and versatile analytical models are of great importance in wireless communication technology.

Keywords: Patch antennas, CST Microwave studio, Reflection coefficient, Antenna gain

1. INTRODUCTION

In general, the transportation of information or a message produced by a source between two specific points through a channel is called communication. Microwave antennas hold the most significant role in today's wireless communication systems. The microstrip antenna concept, which gained significant popularity among microwave antenna types with its high performance, ease of installation, lightness and cheap manufacturing, was first put forward by Deschamps in 1953. Later, Gutton and Baissinot patented a microstrip antenna [1].

Microstrip patch antennas are integral components of wireless systems, and numerous techniques have been developed over the past three decades to increase their bandwidth. These techniques may include frequency-selective surface impedance matching networks, parasitic or multiple resonators, modification geometry of the radiating element, and the use of a substrate with a low dielectric constant or an increase in the thickness of the substrate. The purpose of the microstrip patch antenna is to radiate and receive electromagnetic energy in the microwave range. The operation and performance of a microstrip patch antenna are based on the geometry of the printed patch and the material properties of the substrate on which the antenna is printed [2,3].

Despite this, twenty years passed until photoetching techniques usable thermal and mechanical properties, and low loss rates were developed for a copper or gold-coated substrate with a wide range of dielectric constants, and practical antennas as good as their theoretical models were produced. This was mainly due to the lack of good dielectric bases available. With the development of these bases, microstrip antennas have also undergone rapid development. The first practical antennas were developed by Howel and Munson in the early 1970s. Since then, research and development have been carried out using microstrip antennas' numerous advantages such as lightness, small volume, cheapness, superficial appearance, and suitability for printed circuits; In the broad field of microwave antennas, microstrip patch antennas have pioneered a separate branch and led to various applications [4]. The popularity of microstrip antennas increased after 1970. In the following 1980s, the foundations of the production processes of microstrip antennas were laid [5].

***Corresponding Author Email:** ozlemcoskun@sdu.edu.tr
Submitted: 19.09.2024 **Revision Requested:** 06.10.2024 **Last Revision Received:** 22.10.2024
Accepted: 05.11.2024 **Published Online:** 26.11.2024

Burdur Mehmet Akif Ersoy University Press

Cite this article as: Coşkun, Ö., Erginyürek, N. (2024). Wideband Microstrip Patch Antenna Design at 2.4 Ghz Frequency for Wireless Communication. Scientific Journal of Mehmet Akif Ersoy University, 7(2): 91-98.
DOI: https://doi.org/10.70030/sjmakeu.1185245 https://dergipark.org.tr/sjmakeu

2. MICROSTRIPS ANTENNAS

Microstrip antennas have been frequently used and become widespread, especially in recent years, in mobile communication systems, radar, aircraft, missile satellite and navigation fields. Rectangular H, E shaped, circular etc. Microstrip antennas with different geometric shapes are used according to the conditions required by the application purpose. A wide variety of applications can be achieved by changing the antenna geometry, substrate material type, and feed type to achieve the desired performance for the intended use. The basic configuration of a antenna is thin metallic, as shown in Fig 1. [6, 7, 8].

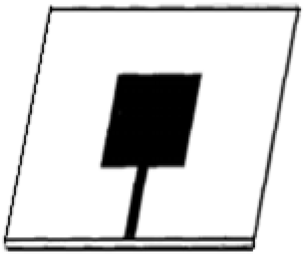

Fig 1. Feeding a microstrip rectangular microstrip antenna

The parameters that directly affect the radiation performance of the microstrip antenna are the dimensions and shape of the radiation element, the thickness of the base material and the dielectric constant. Dielectric base material can be selected arbitrarily in accordance with the designed circuit. The dielectric constant and loss tangent of dielectric materials determine the quality of that material. As the value of the loss tangent increases, the antenna efficiency decreases. In microstrip antennas, one side of the dielectric base material is completely covered with the ground plane, while the other side has a planar conductive strip of any geometry. The structure of this strip determines the properties of the antenna [9].

Microstrip antennas are often preferred due to their low profile, lightweight, low cost, ease of integration with arrays or microwave integrated circuits, and polarization diversity [10]. As shown in Table 1, microstrip antennas have applications in both military and civilian sectors.

Table 1. Some application areas of microstrip antennas

Platform	Systems
Aircraft	Radar, communications, navigation
Missiles	Telemetry
Satellites	Remote sensing, communication, direct TV broadcasting
Ships	Navigation
Land Vehicles	Mobile satellite phone and mobile radio
Other	Biomedical systems

3. MICROSTRIPS PATCH ANTENNAS

In its most basic form, a microstrip patch antenna consists of a ground plane, a dielectric layer and a radiating patch, as shown in Fig 2 [11, 12, 13].

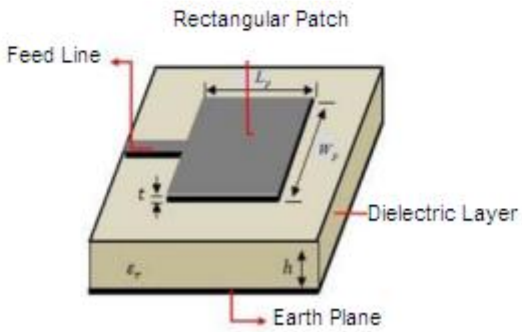

Fig 2. Rectangular microstrip patch antenna

The patch on the upper surface is made of conductive materials such as gold or copper. The characteristic feature of this type of antenna is determined by the geometry of the patch on the radiation surface. The geometric shape of the conductor to be used may vary depending on the area to be used or design features. Square, triangle, circle, ellipse etc. They can be used in different ways. Fig 3 shows the geometric shapes of the microstrip patch antenna.

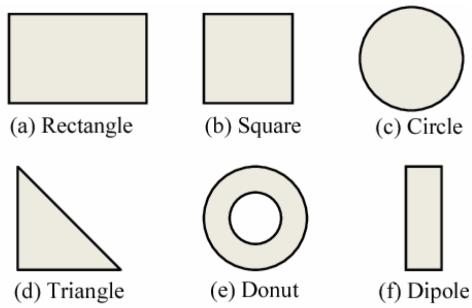

Fig 3. Microstrip patch antenna geometric shapes

In microstrip patch antennas, the radiation characteristics remain similar despite variations in the geometric shape of the conducting patch. Their gains are generally around 5–6 dBi and they have a beam width of 3 dB between 70° and 90° [14].

4. TRANSMISSION LINE MODEL FOR RECTANGULAR MICROSTRIP PATCH ANTENNA

The most common patch geometry in terms of usage area is rectangular shaped patches. The width of the radiating patch is shown in Fig 2, where W_p is its length, L_p is the dielectric constant of the substrate (dielectric layer) used ε_r and its thickness is h. In the mathematical model, first the microstrip patch width W_p and length L_p values are found depending on the operating frequency of the antenna and the determined dielectric constant [15]. Width of rectangular patch W_p

$$W_p = \frac{1}{2 f_r \sqrt{\mu_0 \varepsilon_0}} \sqrt{\frac{2}{\varepsilon_r + 1}} = \frac{c}{2 f_r} \sqrt{\frac{2}{\varepsilon_r + 1}} \quad (1)$$

It can be calculated with the equation. Here c is the speed of light, fr is the resonance frequency, dielectric constant of the gap, ε_0 is the magnetic permeability of the gap.

Since there is a patch on the upper surface of the microstrip antenna and a dielectric layer and air on the lower surface, it has a non-homogeneous structure. This structure causes the electrical permeability value to change. The effective dielectric constant ε_{reff} for the new case is calculated by equation (2).

$$\frac{W_p}{h} \rangle 1 \tag{2}$$

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{-1/2} \tag{3}$$

The electric field causes the patch to behave as if it is electrically larger than its physical size. The electrical length of the L_{eff} patch and the fringing area around the ΔL patch are calculated by equations (4) and (5) [13].

$$\Delta L = 0.412h \frac{\left(\varepsilon_{eff} + 0.3\right)\left(\frac{W}{h} + 0.264\right)}{\left(\varepsilon_{eff} - 0.258\right)\left(\frac{W}{h} + 0.8\right)} \tag{4}$$

$$L_{eff} = \frac{1}{2 f_r \sqrt{\varepsilon_{eff}}\sqrt{\mu_o \varepsilon_o}} \tag{5}$$

If the actual length of the patch is Lp, it is calculated by equation (6).

$$L_p = L_{eff} - 2\Delta L = \frac{1}{2 f_r \sqrt{\varepsilon_{eff}}\sqrt{\mu_o \varepsilon_o}} - 2\Delta L \tag{6}$$

The dimensions of the dielectric material are given in equation (7) and equation (8).

$$W_m = 6h + W \tag{7}$$

$$L_m = 6h + L \tag{8}$$

Length of indentation, y_0

$$R_{in}(y = y_0) = \frac{1}{2(G_1 \pm G_{12})}\cos^2\left(\frac{\pi}{L} y_0\right) \tag{9}$$

$$= R_{in}(y = 0)\cos^2\left(\frac{\pi}{L} y_0\right) = \frac{1}{2G_1}\cos^2\left(\frac{\pi}{L} y_0\right)$$

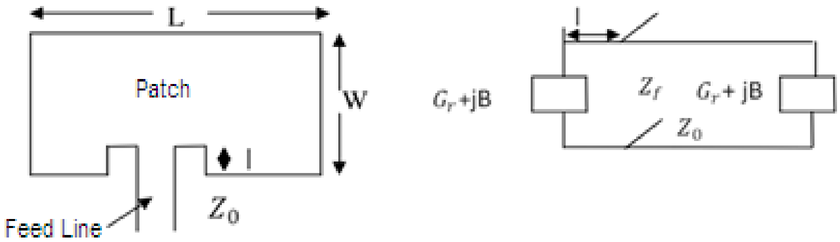

Fig 4. Modeling of microstrip patch antenna

5. ANTENNA DESIGN AND SIMULATION

Antennas are created by placing a radiating plane onto the dielectric substrate in the desired geometry. Thickness, type and dielectric constant of the base material; It is important in design because it directly affects the antenna's characteristics such as bandwidth and radiation. Therefore, the first thing to do for microstrip antenna design is to choose a suitable base material. The patch and ground plane generally have regular geometries. Although the patch geometry that provides radiation is generally planar, non-planar geometries are also used [16].

In the study, FR-4 material with a relative dielectric constant (ε = 4.3), loss tangent of $\tan\delta = 0.019$ was preferred as the suitable substrate material, and the dielectric material thickness was preferred as h = 1.6 mm. The designed microstrip antenna is desired to operate at 2.4 GHz operating frequency and the software called CST Microwave Studio was used for the design. The geometry of the microstrip patch antenna to be designed is given in Fig 5. Here, the width of the patch is denoted by W, the length of the patch is denoted by L, and the dimensions of the dielectric material are denoted by W_m and L_m

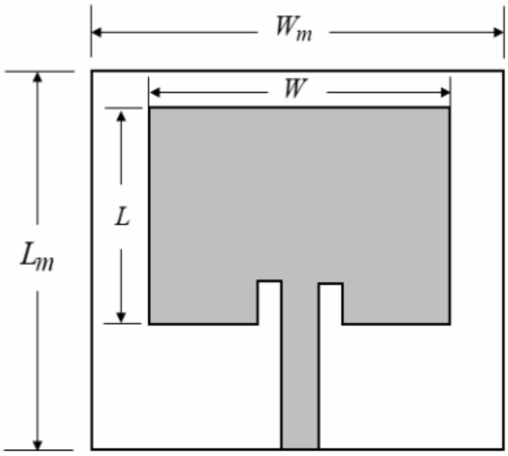

Fig 5. Rectangular microstrip patch antenna geometry

Table 2. Dimensions of the designed patch antenna

Patch Width (W)	38.39 mm
Patch Length (L)	28.77 mm
Material Width (W_m)	100 mm
Material Length (L_m)	100 mm
Feed Line Width (W_p)	3.13 mm
Indent Width (y_m)	1.5 mm
Indent Length (y_0)	7.0 mm
Grounding Thickness	0.035 mm

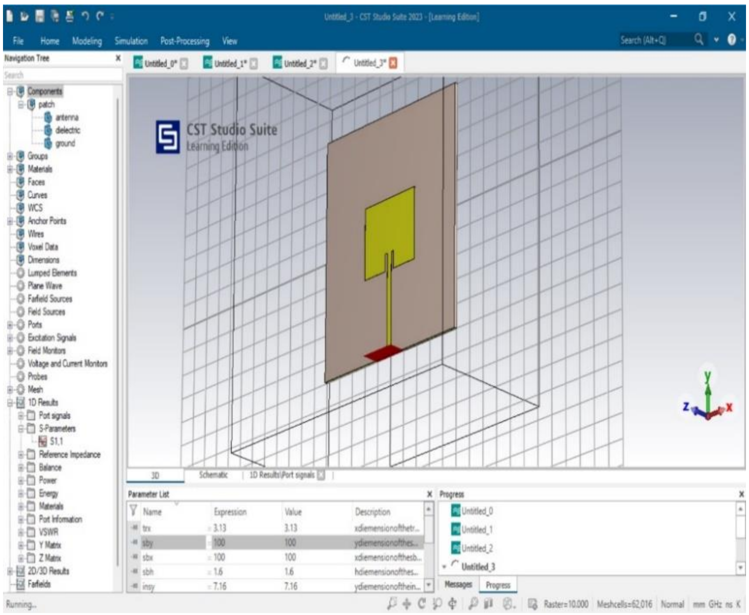

Fig 6. CST Studio representation

6. RESULTS

The reflection coefficient of the designed rectangular microstrip patch antenna is given in Fig 7.

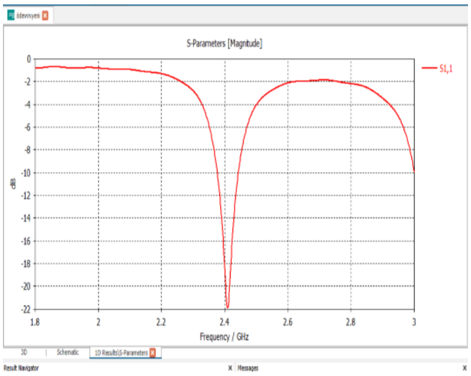

Fig 7. S_{11} graph

The gain and directivity diagrams of the antenna are given in Fig 8 and Fig 9. Antenna at 2.4 GHz resonance frequency; It has a maximum gain of 2.27 dB and a maximum directivity of 7.28 dB in the same direction.

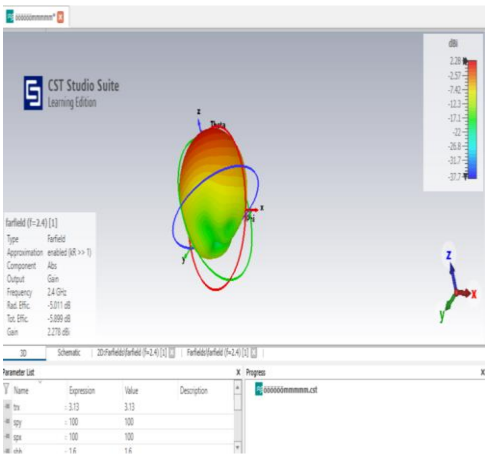

Fig 8. Gain diagram

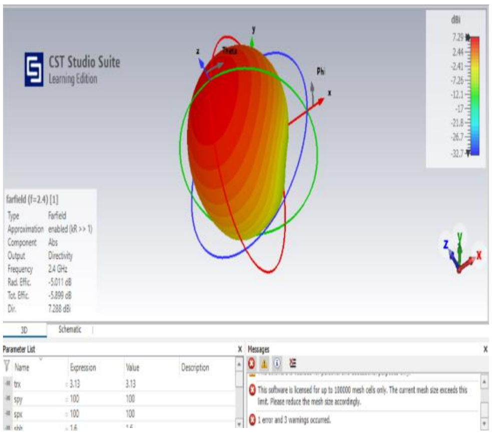

Fig 9. Directivity diagram

The power gain radiation diagram is shown in Fig 10. The radiation diagram is a graph that shows the angular change of the power (electromagnetic field intensity) emitted by the antenna in a certain distant area of the antenna, at a fixed distance. It was determined that Phi 270 value had a maximum directivity of 7.28 dB and a maximum gain of 2.27 dB in the same direction.

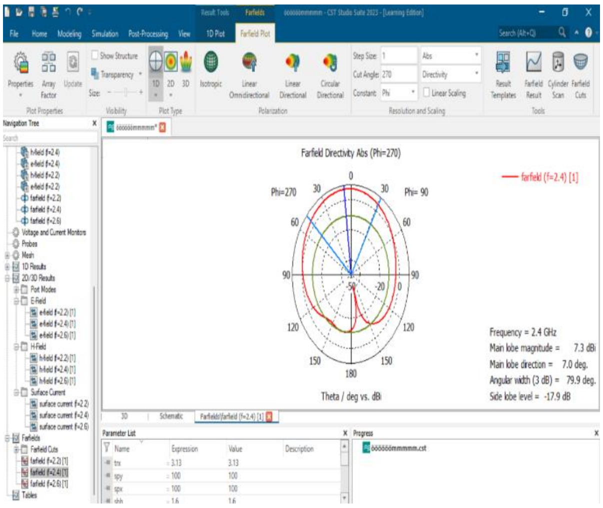

Fig 10. Power gain radiation diagram

Table 3. Comparison of the designed study with the previous study

References	Operating Frequency (in GHz)	Gain (dB)	Max. Directivity (dB)	Return Loss (dB)
[16]	2.4	2.97	3.3	-16
Proposed Antenna	2.4	2.27	7.28	-22

7. CONCLUSIONS

Microstrip antennas; They are highly preferred in communication systems because they can be produced cheaply with modern printed circuit technology, have small dimensions, do not damage the structures to be joined, and do not consume too much power. Within the scope of this study; In the 2.4 GHz band, which is widely used in wireless communication systems, a microstrip line with a characteristic impedance of 50 Ω was used. With developing technology; An antenna design has been made to meet the need for broadband microstrip patch antenna designs arising from reasons such as increasing the data transfer rate and uninterrupted data transfer. According to the simulation results made with the CST Microwave Studio program, the antenna at the 2.4 GHz resonance frequency; It was determined that Phi 270 value had a maximum directivity of 7.28 dB and a maximum gain of 2.27 dB in the same direction. Aiming to achieve the desired performance for the intended use in future studies; A wide variety of applications can be achieved by changing the antenna geometry, substrate material type, and feed type.

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Techno-Science *Paper ID: 1185245*